Water Quality Standards Academy

Aquatic Life Criteria

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Introduce myself and office.

This is a brief introduction to criteria development covering the various aspects of water quality criteria. This module is one of four presentations on specific water quality criteria.

We are talking about National Recommended Water Quality Criteria or Ambient Water Quality Criteria or 304(a) criteria in reference to the CWA section which covers the topic.

Ambient refers to open waters such as rivers, lakes and streams, as opposed to closed water supply systems that distribute treated water or wastewater

Section 304(a)(1) of the Clean Water Act requires EPA periodically to review and publish criteria for water quality that accurately reflect the latest scientific knowledge on the kind and extent of all identifiable effects on environmental health, human health and welfare.

These criteria are not Federal regulations; however, they are usually used by the States and authorized Indian Tribes to establish their own standards. They present scientific data and guidance on the effects of pollutants that can be used to derive regulatory requirements, including the promulgation of water quality-based effluent standards *(the Clean Water Act, section 302)*, water quality standards *(the Clean Water Act, section 303)*, or toxic pollutant effluent standards *(the Clean Water Act, section 307)*.

National Recommended Water Quality Criteria

- Human Health Criteria (Fish consumption)
- Aquatic Life Criteria
  - Acute and Chronic
  - Freshwater and Saltwater

		Freshwater		Saltwater		Human Health for the consumption of		
Priority Pollutant	CAS Number	CMC (acute) (µg/L)	CCC (chronic) (µg/L)	CMC (acute) (µg/L)	CCC (chronic) (µg/L)	Water + Organism (µg/L)	Organism Only (µg/L)	FR Cite/ Source
1 Antimony	7440360					5.6	640	65 FR 66443
2 Arsenic	7440382	340	150	69	36	0.018	0.14	65 FR 31682 57 FR 60848

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As we have mentioned in previous modules, **a criterion is a measure of water quality designed to ensure the protection of designated uses.**

This module will introduce the procedures used to calculate numerical criteria to protect aquatic life designated uses.

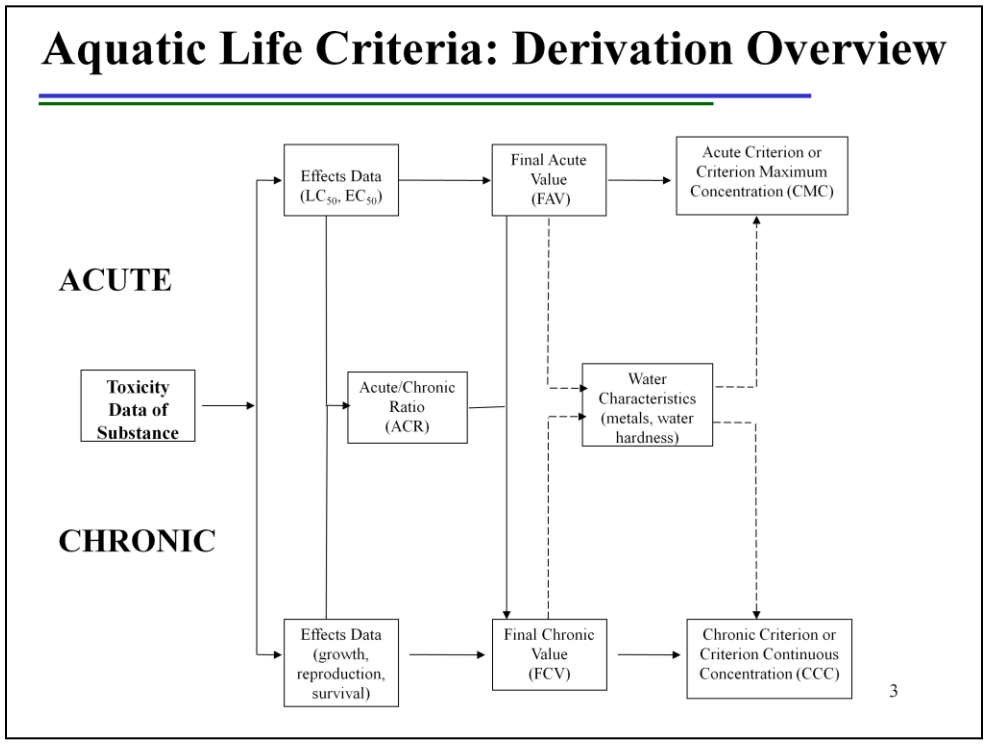
EPA's aquatic life criteria consist of three components:

- **magnitude: the concentration of a pollutant;**
- **duration: the period of time over which this concentration is averaged; and**
- **frequency: how often the criteria can be exceeded.**

It should be noted that when I say **"guidelines**," I am referring to the **1985** ***Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses***.

We do not consider wildlife, unless it is aquatic-dependent wildlife, nor sediment toxicity. Each is covered by independent methods published by EPA.

Note the table in the slide above. There are 4 aquatic life criterion values listed: freshwater, saltwater with acute and chronic for each. Not every pollutant criteria has all 4, this is data dependent.



Here is an overview flowchart of the basic steps we follow to derive national recommended ALC under the CWA Section 304(a).

Explain the Reason for Using Two Concentrations (CCC and CMC)

Two concentrations are specified in the criteria statement. Need to be considered when aquatic organisms are exposed to pollutants.

-**exposure concentrations and the length of exposure**.

-In other words, an aquatic organism can be exposed to a **higher concentration of pollutant for a shorter period of time to limit adverse effects** (Criterion Maximum Concentration).

-Aquatic organisms **can tolerate being exposed to low levels of pollutants for longer periods of time** (Criterion Continuous Concentration).

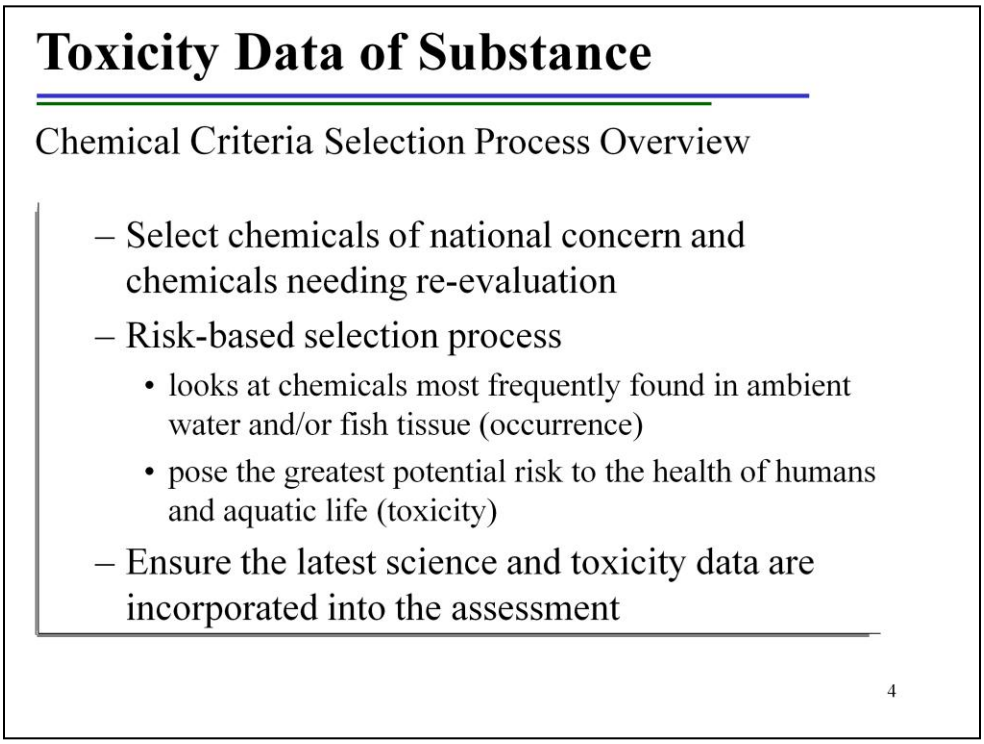
Examples of "unacceptable" adverse effects are: reductions in reproduction, growth, or survival and immobilization in some invertebrates..

Summarize Process for Numerical Criteria Derivation

When developing numerical criteria for the protection of aquatic life, acute and chronic aquatic toxicity data for plants and animals is considered. *A* Final Acute Value/CMC is calculated from the acute toxicity data, and a Final Chronic Value/CCC is calculated from chronic data or a combination of acute and chronic data.

But first I am going to explain **how we determine what chemical criteria to develop by evaluating the toxicity data of a particular substance.**

(FYI - *Bioaccumulation is the process by which there is a net accumulation of a chemical to an aquatic organism, but accounts for all routes of exposure including: water, sediment, and food.)*



In HECD/ERAB we use a chemical criteria selection process by which we select chemicals of emerging national concern and chemicals with existing ALC needing re-evaluation based on new toxicity data that may result in a change to the criteria.

Aquatic Life Criteria Selection Process

- Review chemical lists from regions, States and stakeholders
- Compile list of chemicals that appear on multiple priority lists
- Categorize chemicals according to availability of toxicity data to meet *1985 Guidelines* Minimum Data Requirements
  - Guidelines require data for at least 8 families for acute and 3 families for chronic criteria derivation (ACR)
- Score & Rank chemicals with toxicity data for 6 or more families

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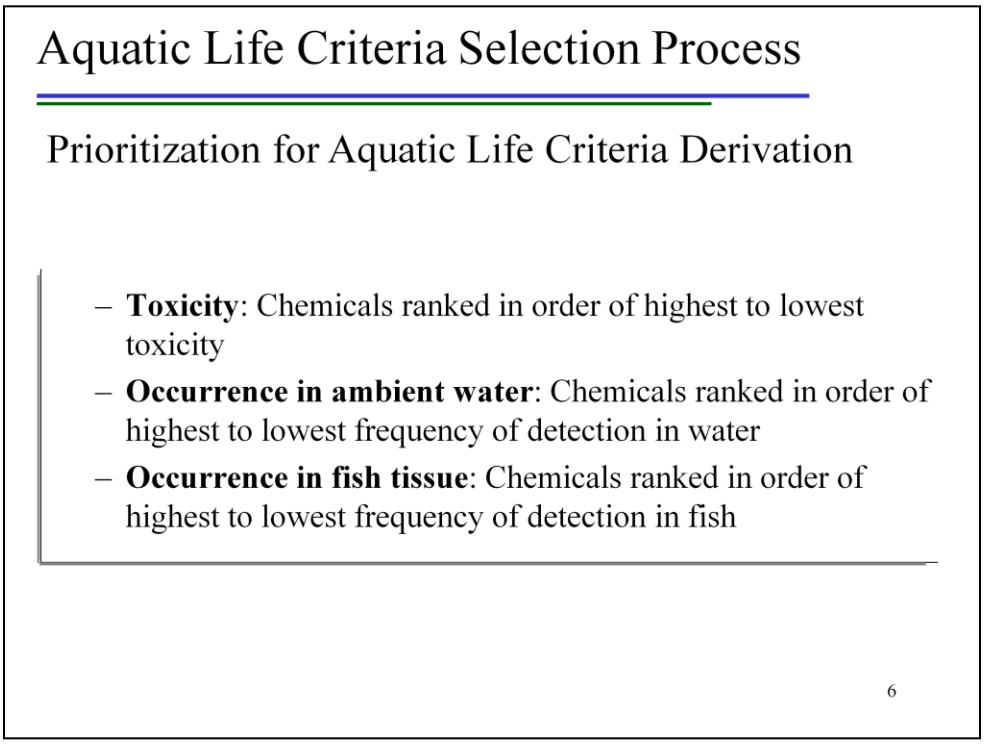


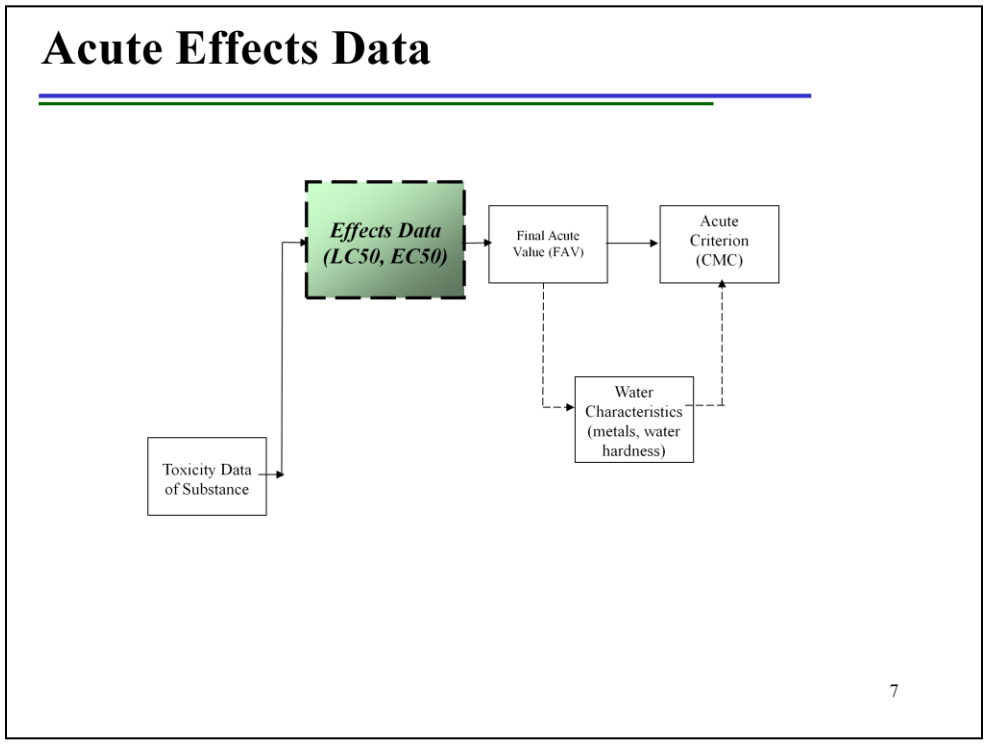
We follow a risk-based process to select chemicals for criteria development including:

- evaluation of chemicals most frequently detected in surface water &/or fish tissue (occurrence)

- evaluation of tox data to determine the potential risk to aquatic life (toxicity)

We search the scientific literature for tox data on the substance of interest to ensure the latest science is incorporated and to evaluate if sufficient high quality data exists to derive a criteria.

Our search uses ECOTOX, which is an EPA system for categorizing open literature data related to the toxicity of pollutants. This online system is searchable by the public. ERAB uses the public list as well as the rejected studies list to assure that we have reviewed all of the available data on a chemical.

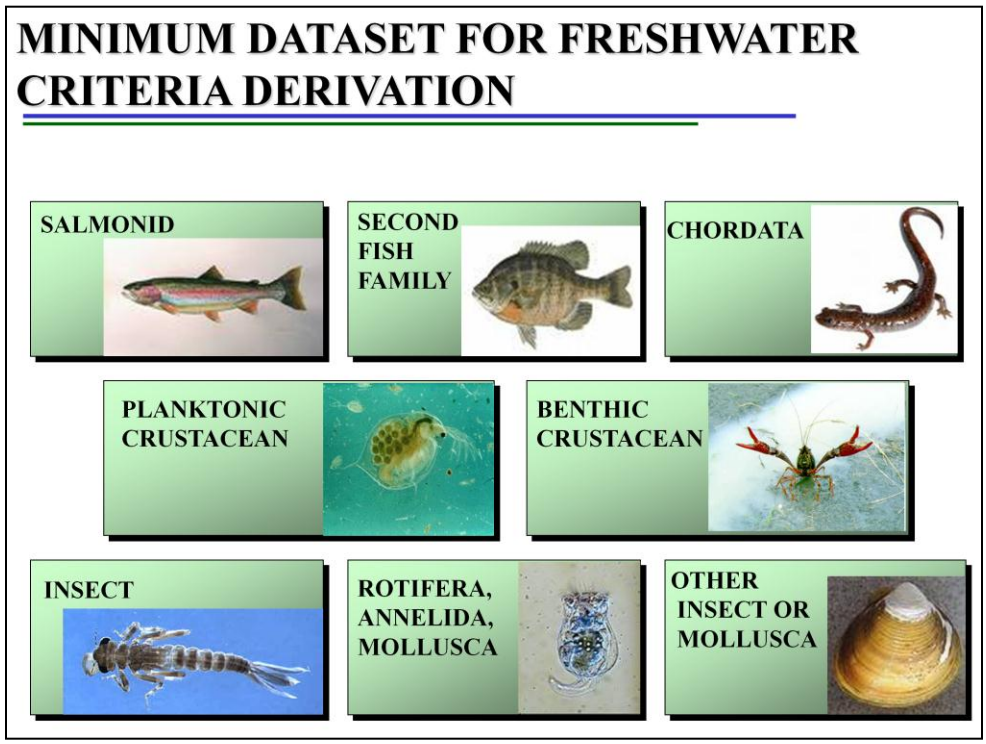


All data used should be well documented. Rejection of data is noted with description.

Sufficient information needs to be reported to evaluate the study's suitability for use in deriving national criteria. An example of acceptable test procedures are outlined in the American Society for Testing and Materials (ASTM) Standards. The 1985 Guidelines also provides information regarding test acceptability. Examples of unacceptable test data would include excessive mortality of control organisms, inappropriate culture, unmeasured toxicant levels (critical if volatile or readily degraded), etc.

All organisms are classified into a hierarchy of groupings or taxa, thus the name *taxonomy*. In hierarchical order, these taxa comprise:

Kingdom, Phylum, Class, Order, Family, Genus, and Species.

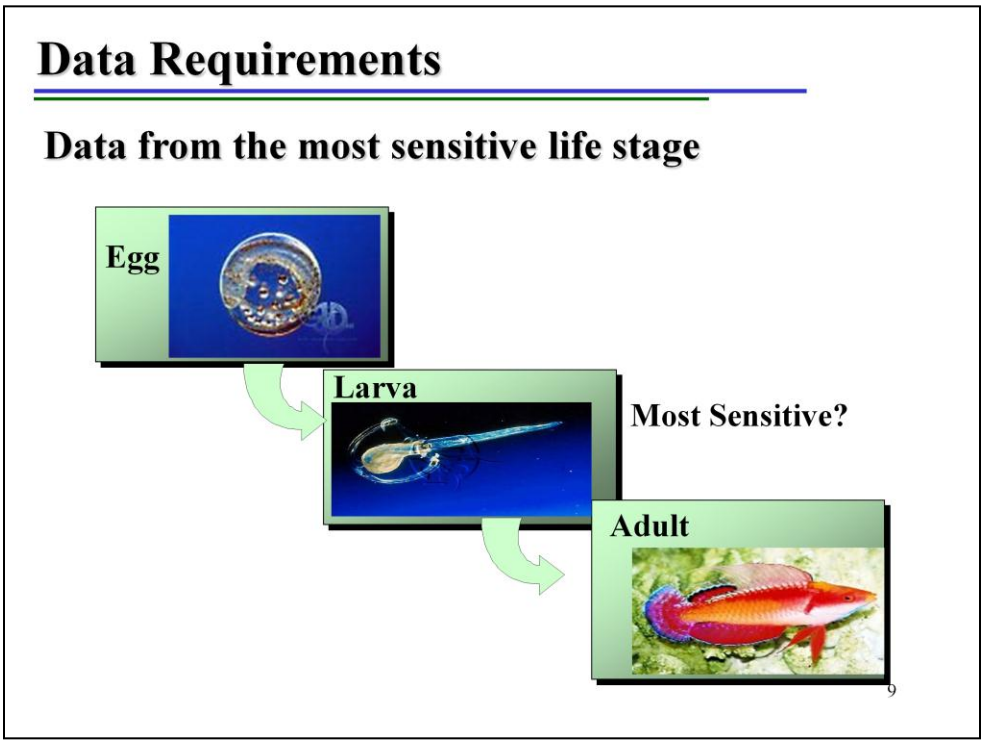


To derive a criterion for freshwater aquatic organisms and their uses, data should exist for at least one species *(the most specific grouping)* of freshwater animal in at least eight different taxonomic families.

These groups of organisms are selected so that the diversity and the sensitivities of a broad range of aquatic life are represented in the criteria values in order to estimate a very low level of potential effect.

Requirement includes:

- A fish in the family Salmonidae; (coldwater, sensitive fish)
- a second bony fish family, preferably a **commercially or recreationally important warmwater species (such as bluegill or channel catfish**);
- a third family in phylum **Chordata (such as another fish family or amphibian**);
- a **planktic crustacean** (for example, **cladoceran or copepod);**
- a **benthic crustacean** (such as ostracod, isopod, **amphipod, or crayfish**);
- an insect (a mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, or midge);
- a family in **a phylum other than Arthropoda or Chordata (such as Rotifera, Annelida, or Mollusca**); and
- **a family in any order of insect or any phylum not already represented (such as Mollusca**).



Explain Use of Data from the Most Sensitive Life Stage

For the calculation of the Species Mean Acute Value, **only data for the most sensitive life stages of a given species should be used**. For example, the young life stages (like egg and larva) may be used. If sensitivity of life stages is unknown, the available data is used.

Conversely, this means that you **should not use one particular life stage if it is unusually resistant to the material as compared with other life stages**.

These groups of organisms are selected so that the most sensitive point in an aquatic organisms life are represented by the criterion.

Confidence in a criterion usually increases as the amount of available acceptable data increases. Thus, collecting additional data is desirable. These MDRs are the minimum requirement, there is no maximum requirement.

Toxicity Test Data

Data Sources and Endpoints

Data is pulled from ecological toxicity database (Ecotox, maintained by EPA). This is constantly updated, on a compound specific basis, from literature.

A data pull is also performed from a number of current sources, to be certain that data is current and accounted for.

Acute: 48-hr or 96-hr toxicity test

- measured as LC_{50}, EC_{50}
- lethal concentration/effects concentration of 50% tested organisms

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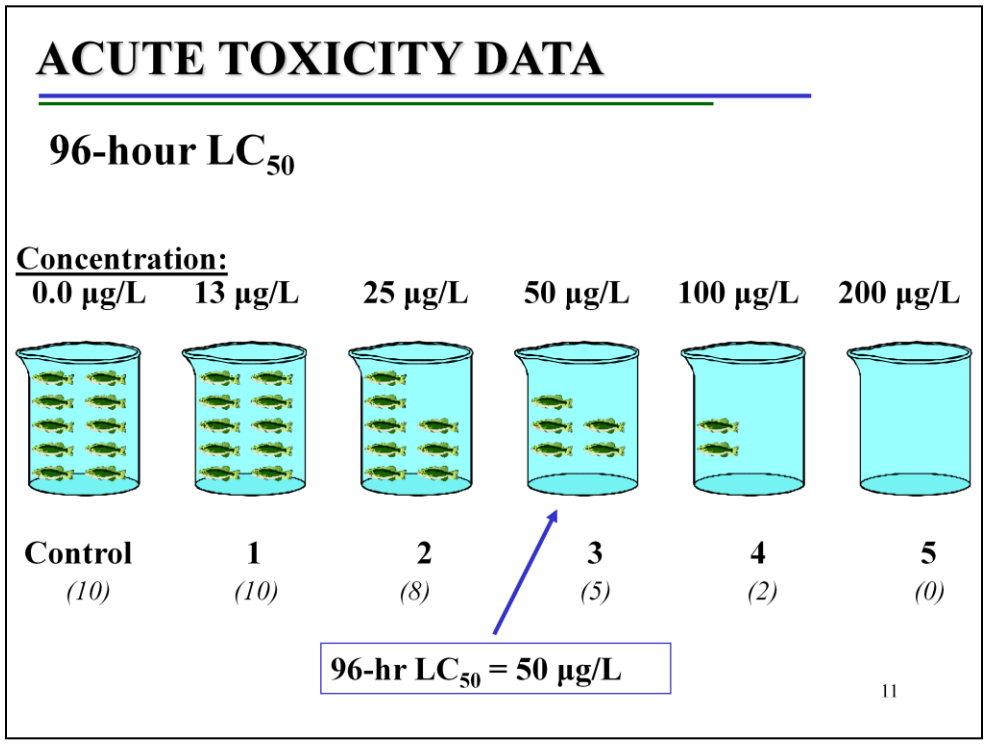


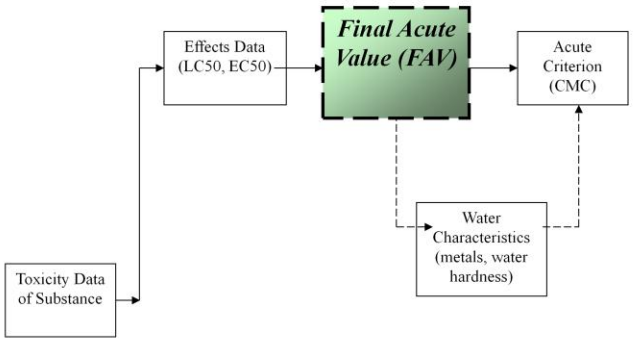
Explanation of Required Data

[for more information, see Guidelines, pp. 23-25]

An LC50 is a specific concentration of a chemical that is lethal to 50% of the organisms exposed for a specific amount of time. An “EC50" is a concentration that caused a specified effect on 50% of the organisms over a given time period.

In this illustration, the concentration in the 4th beaker would be the LC50 since 50% of the organisms died.

Final Acute Value (FAV)



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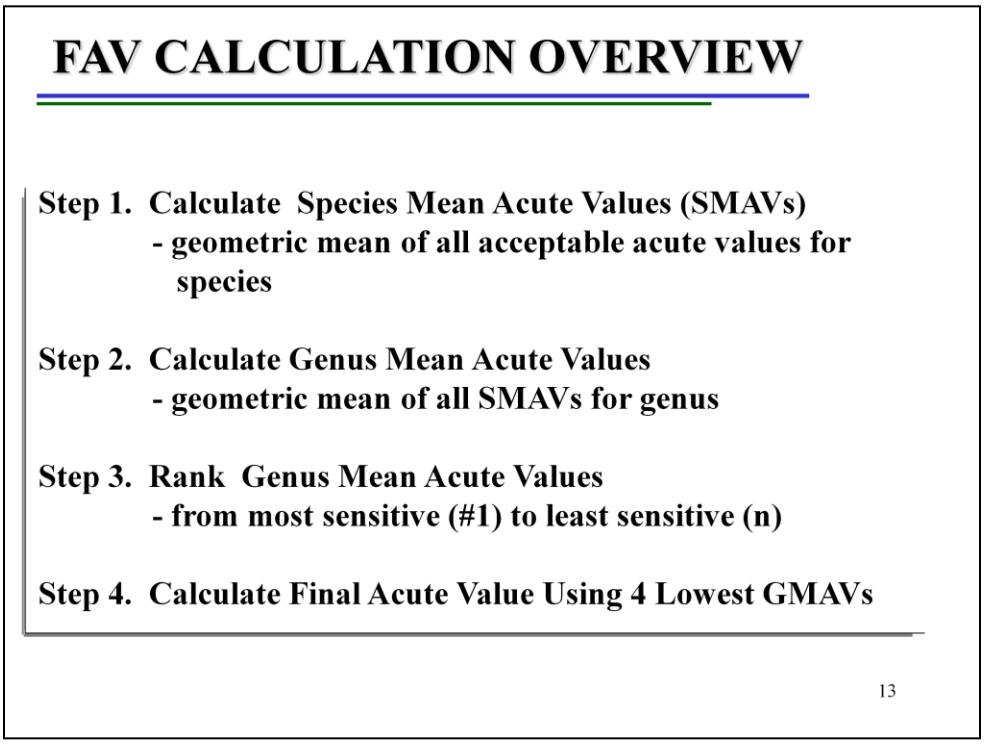

Summarize the Calculation of the FAV

After appropriate data have been collected and analyzed for quality and completeness, the criterion can be calculated.

The details of the FAV calculation are summarized on the following slides.

SPECIES MEAN ACUTE VALUE (SMAV)

Daphnia magna **EC50**		**25 µg/L**
Daphnia magna **EC50**		**30 µg/L**
Daphnia magna **EC50**		**35 µg/L**
Daphnia magna **EC50**		**28 µg/L**
	SMAV =	**29 µg/L**

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The initial step is to calculate the geometric mean of appropriate tests of short-term toxicity for all species, the Species Mean Acute Value or SMAV.

GENUS MEAN ACUTE VALUE (GMAV)

Daphnia magna	SMAV	29 µg/L
Daphnia pulex	SMAV	38 µg/L
Daphnia ambigua	SMAV	42 µg/L

GMAV = 36 µg/L

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From these SMAVs, a Genus Mean Acute Value (GMAV) is then calculated for each genus in the same manner.

Both the SMAV and the GMAV are geometric means.

Table 3 - Rank GMAVS

RANK	GMAV (µg/L)	Species	SMAV (µg/L)
4	100	Rainbow Trout, *Oncorhynchus mykiss*	100
3	36	Cladoceran, *Daphnia ambigua*	42
		Cladoceran, *Daphnia pulex*	38
		Cladoceran, *Daphnia magna*	29
2	25	Amphipod, *Gammarus pseudolimnaeus*	25
1	19	Amphipod, *Hyalella azteca*	19

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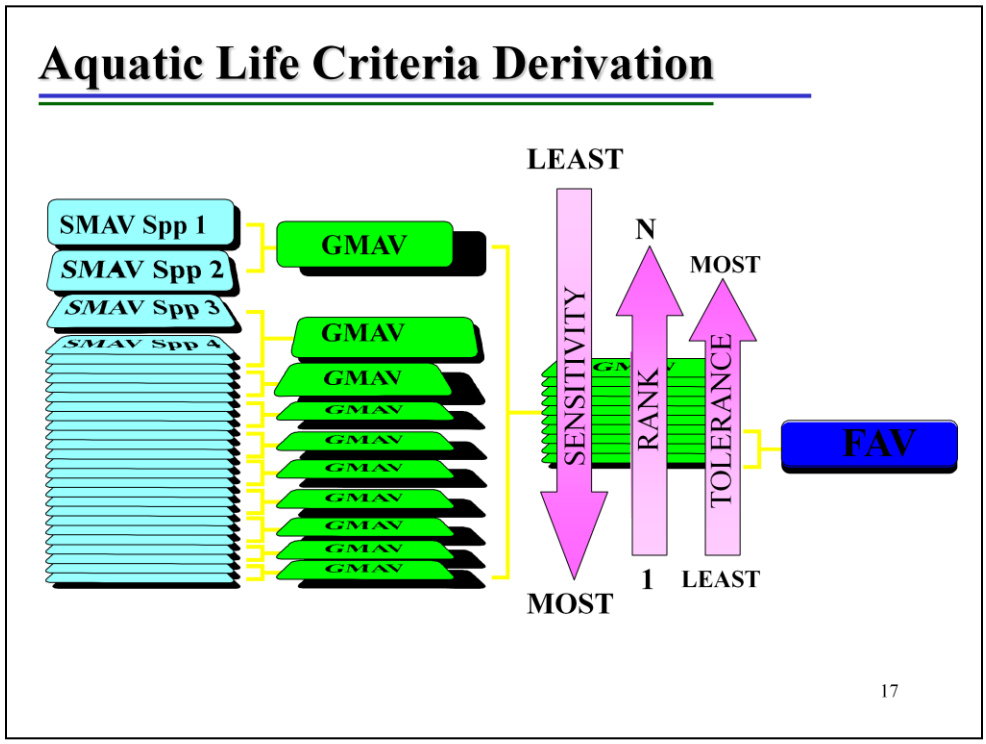
The GMAVs are ordered and ranked based on sensitivity.

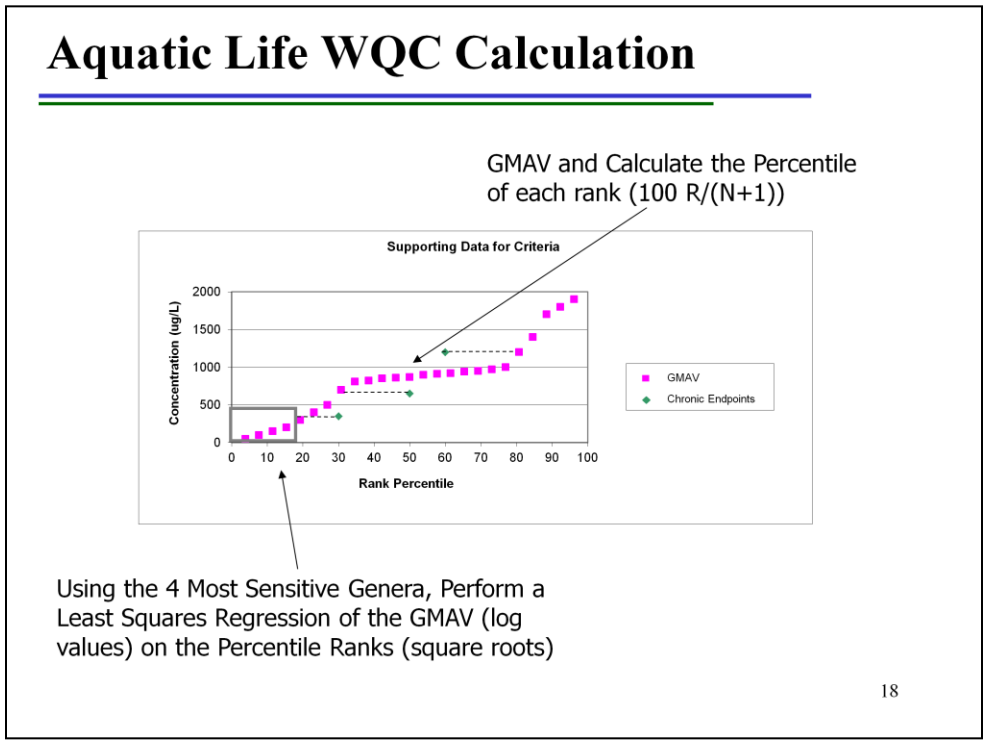
If a Genus only has a single SMAV, that SMAV is then considered the GMAV as well.



Once the values are ranked, a cumulative probability is calculated.

The **cumulative probability is simply the chance that an organism will die when exposed to a given concentration or below.**

For example, if the cumulative probability were 0.4, we would expect 40 percent of the organisms exposed to this concentration to exhibit an adverse effect.



We are interested in the concentration associated with a **cumulative probability of 0.05**. This is the estimated 5th percentile of all values.

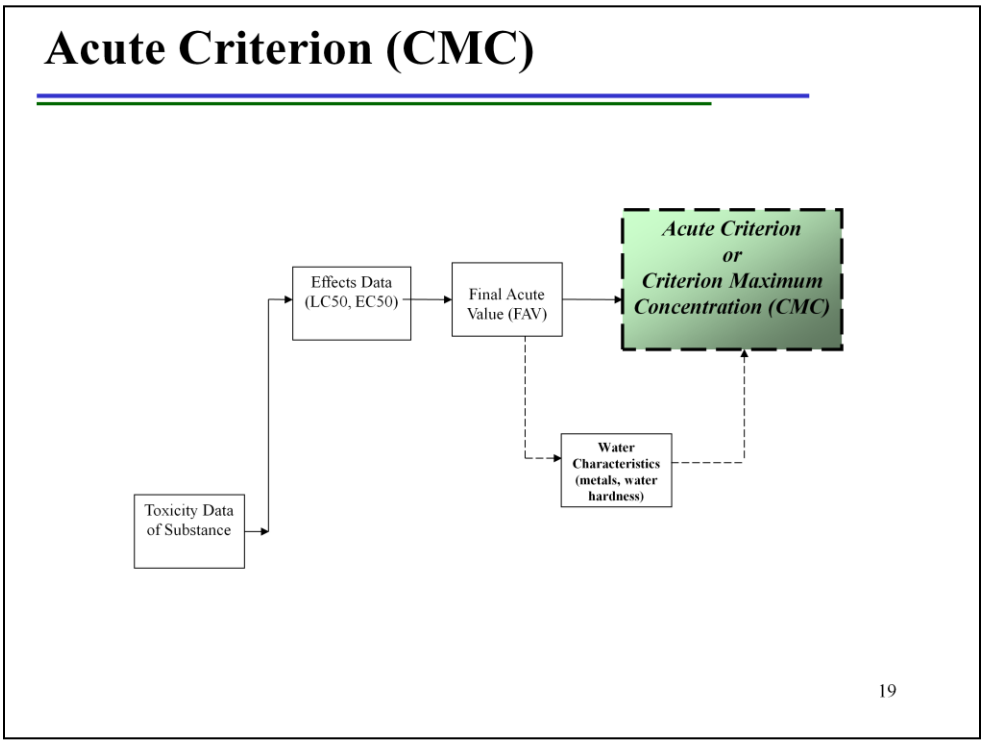
In most cases, **there are not enough data in the data set to interpolate the 5th percentile concentration, so typically the four lowest GMAVs are selected to extrapolate** to the 5th percentile concentration. The GMAVs closest to the 5th percentile of toxicity are used to calculate the FAV.

Explain the Reasoning Behind Using the 5th Percentile in the FAV Calculation

If acceptable data are available for a large number of appropriate taxa from an appropriate variety of taxonomical and functional groups, a reasonable level of protection will probably be provided if all except a small fraction of the taxa are protected.

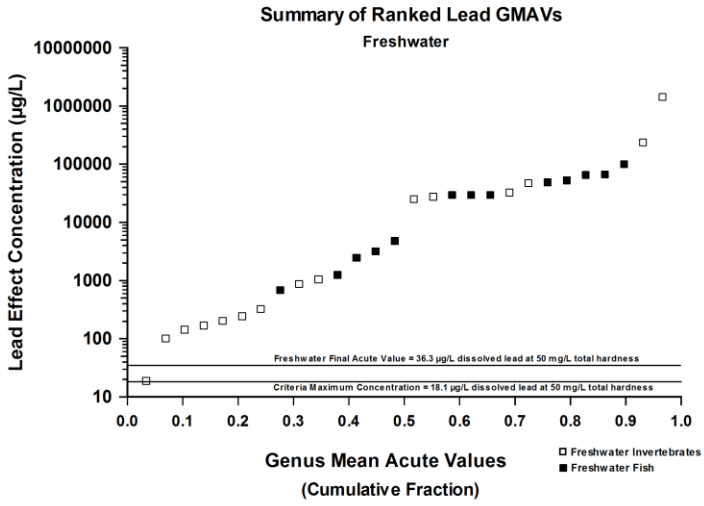
To be practical, EPA selected the 5th percentile as this small fraction.

Thus the FAV represents the 5th percentile of all potential species in the SSD based on the empirical evidence.



Next we calculate the Criterion Maximum Concentration (the acute criterion value itself) by dividing the FAV by 2 for added conservativism. This value was derived by examining all existing test data and determining what value would bring the FAV below a measurable level of effect.

Aquatic Life WQC Calculation



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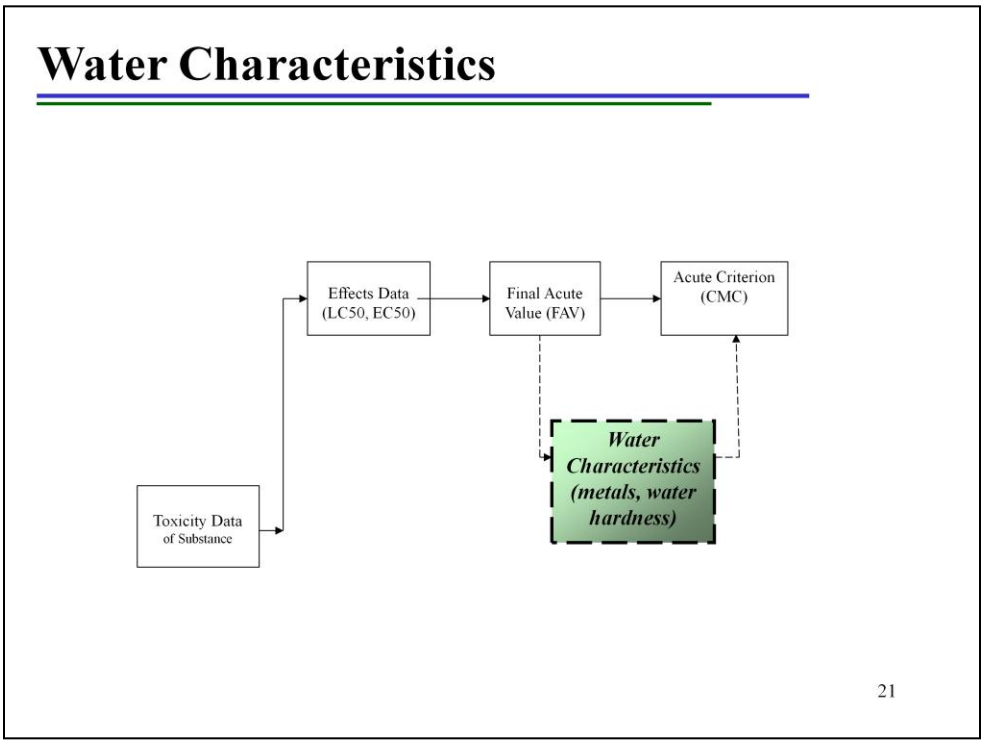
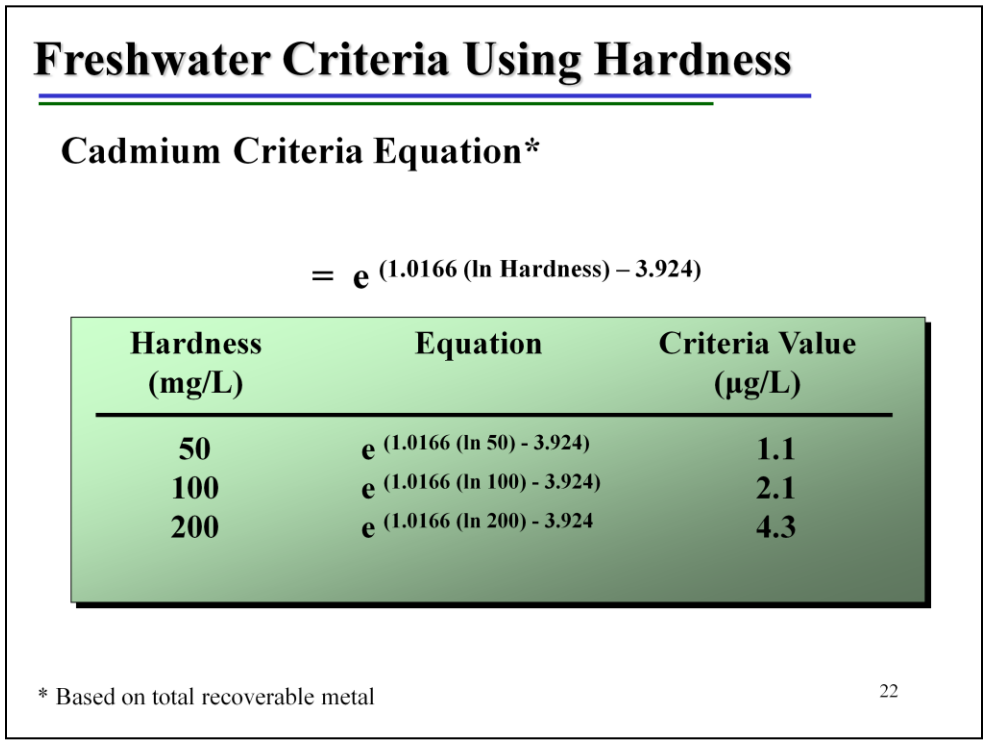
The above example is an actual plot of GMAVs at their respective probability rankings. This is an SSD or species sensitivity distribution. The horizontal lines are the calculated FAV and CMC. You will note that a single species falls in the approximate same area as the criterion. This can occur, and is largely a result of single random tests in the data set or unique sensitivity of a specific species. However, the implementation of the criterion should be protective of that species (recall the discussion of frequency and duration).



For some toxicants (e.g. metals) the toxicity level is dependent on various water characteristics (e.g. hardness, pH)

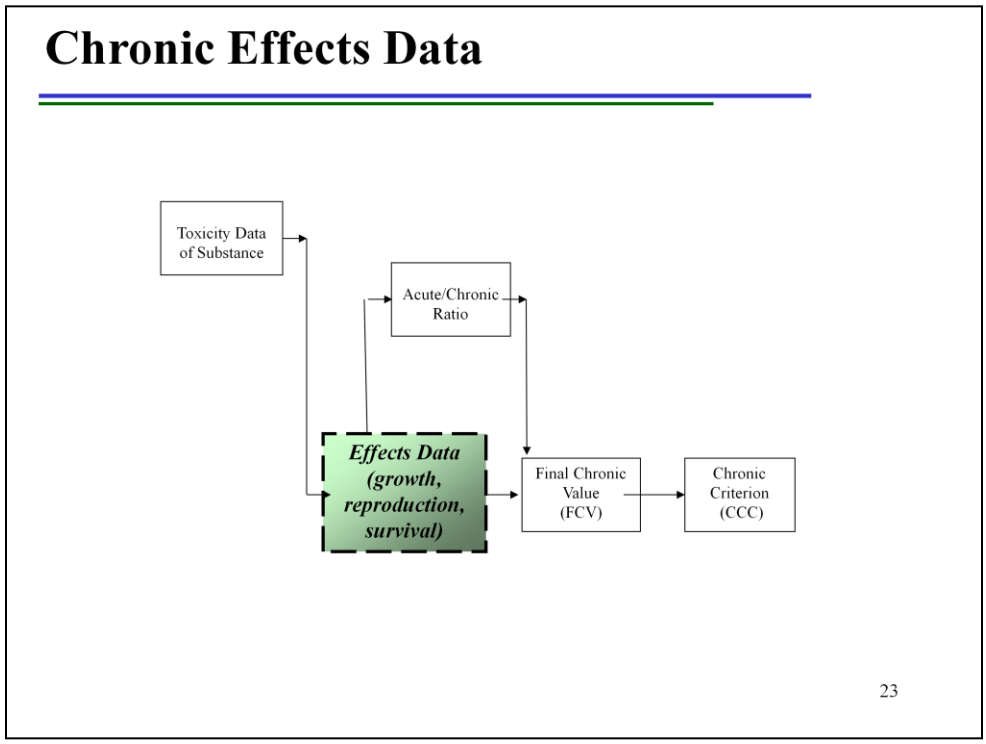


This slide shows the freshwater criterion for cadmium based on a hardness equation. As you can see, the final criterion value varies with the hardness value of your water body of concern.

EPA worked cooperatively with various organizations to develop a new model called the biotic ligand model, or BLM. The BLM predicts acute toxicity based on site-specific water quality parameters like pH, hardness, and dissolved organic carbon (DOC). This model is currently available only for freshwater copper. This model accounts for the major variables that effect toxicity rather than only accounting for hardness.

An example of a hardness equation used in a criteria statement is shown in the freshwater criterion statement in Handout 9-3 on page 9-11 of your manual.

****When the Species Mean Acute Value from a commercially or recreationally important species is lower than the calculated Final Acute Value, this other value should replace the Final Acute Value.** This will ensure protection of the commercially or recreationally important species.



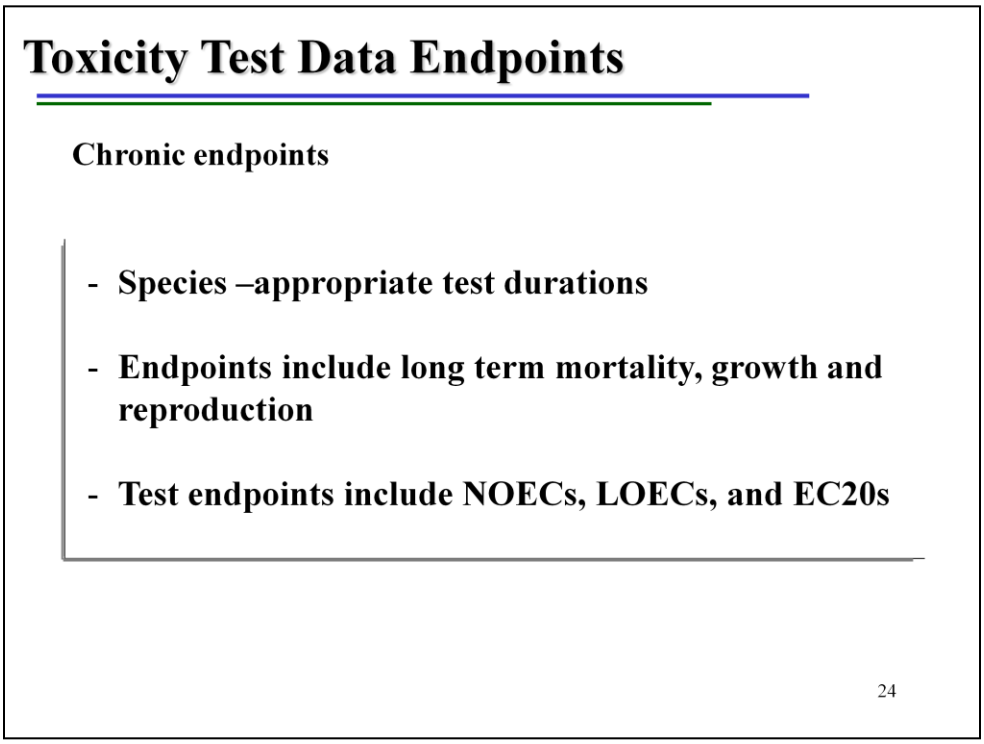
Introduce the CCC

The next item we are going to discuss is the calculation of the Criterion Continuous Concentration or CCC. The CCC can be derived from the Final Chronic Value (FCV), a Final Plant Value (FPV), or a Final Residue Value (FRV).

Explain the Final Chronic Value

Chronic values should be based on the results of appropriate flow-through chronic tests. Concentrations of test material should be measured at appropriate times during the test to verify that chemical exposure was consistent.

The Final Chronic Value can be calculated by using chronic data for eight taxonomic families in the same manner as the Final Acute Value, or an acute-chronic ratio (ACR) can be used to derive the value. In many cases, it may not be possible to calculate a Final Chronic Value based on the eight family procedure, due to lack of sufficient chronic data.



1985 Guidelines describes some specifics for acceptable chronic test endpoints.

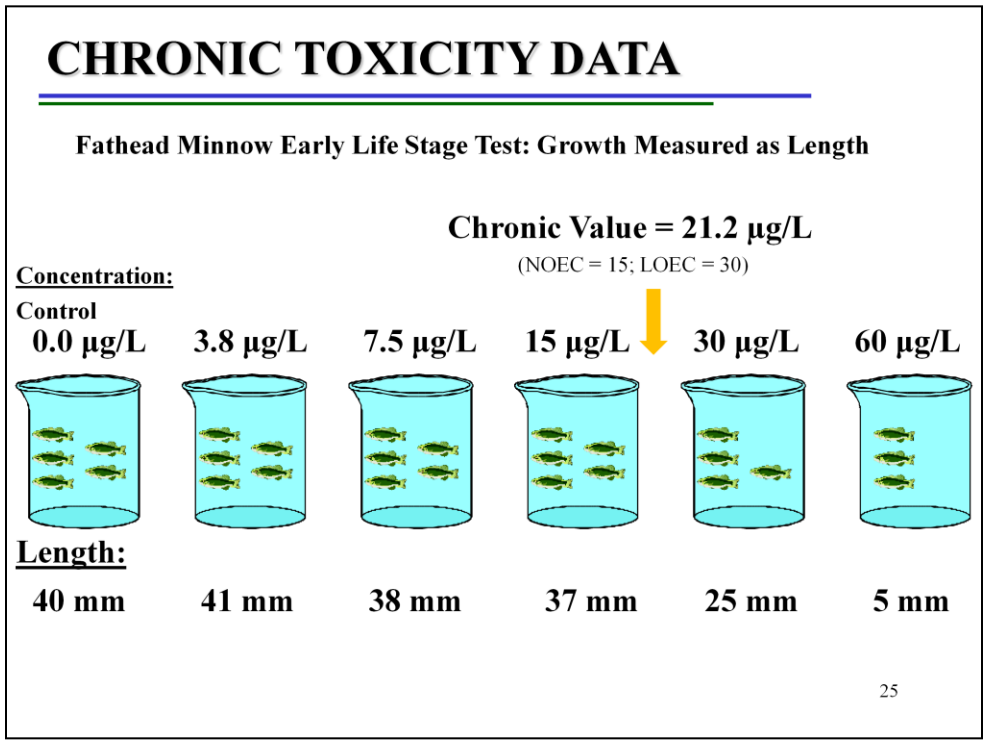
Other types – Complete life cycle

NOEC = No Observed Effect Concentration

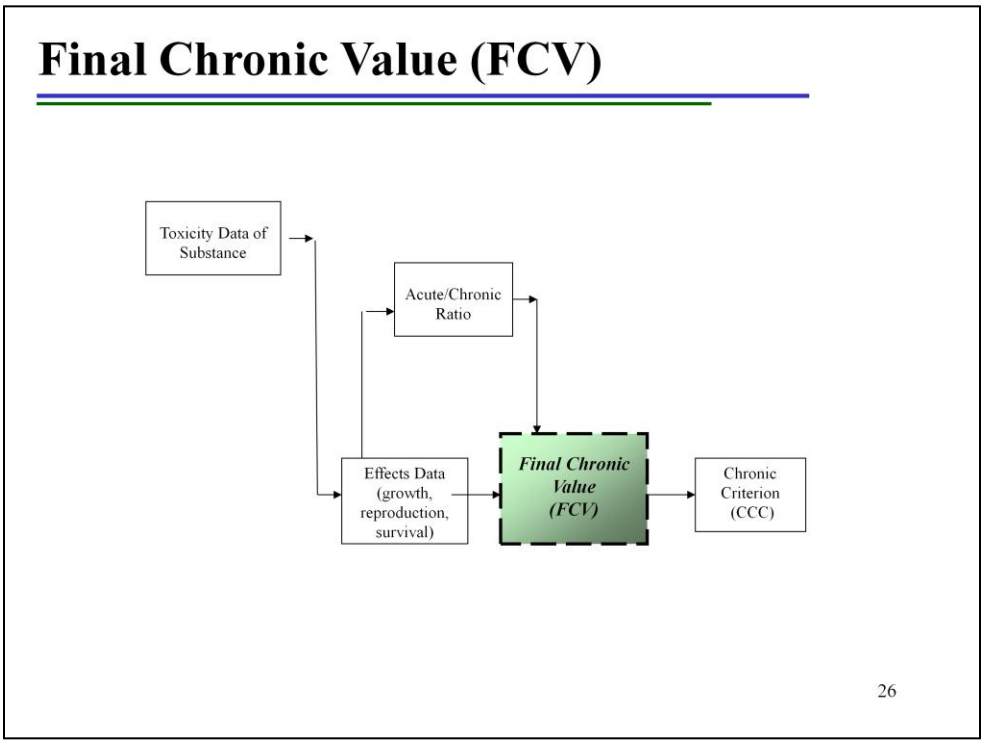
LOEC = Lowest Observed Effect Concentration

EC20 = concentration producing an effect in 20% of test organisms

Test times relate to the organism. For short lived organisms, for example, daphnids, the test is 96 hours. For most vertebrates it is a early life stage or long term study.



A chronic value can be the geometric mean of a No Observed Effect Concentration (NOEC) and the Lowest Observed Adverse Effect Concentration (LOEC) or some other statistically defined value such as a point estimate from a regression analysis (EC20, EC10, etc.).



Review Final Chronic Value

As with acute toxicity, if the **chronic toxicity of the material to aquatic animals has been shown to be related to a water characteristic**, a Final Chronic Equation should be derived based on that water characteristic. (e.g.., most metals)

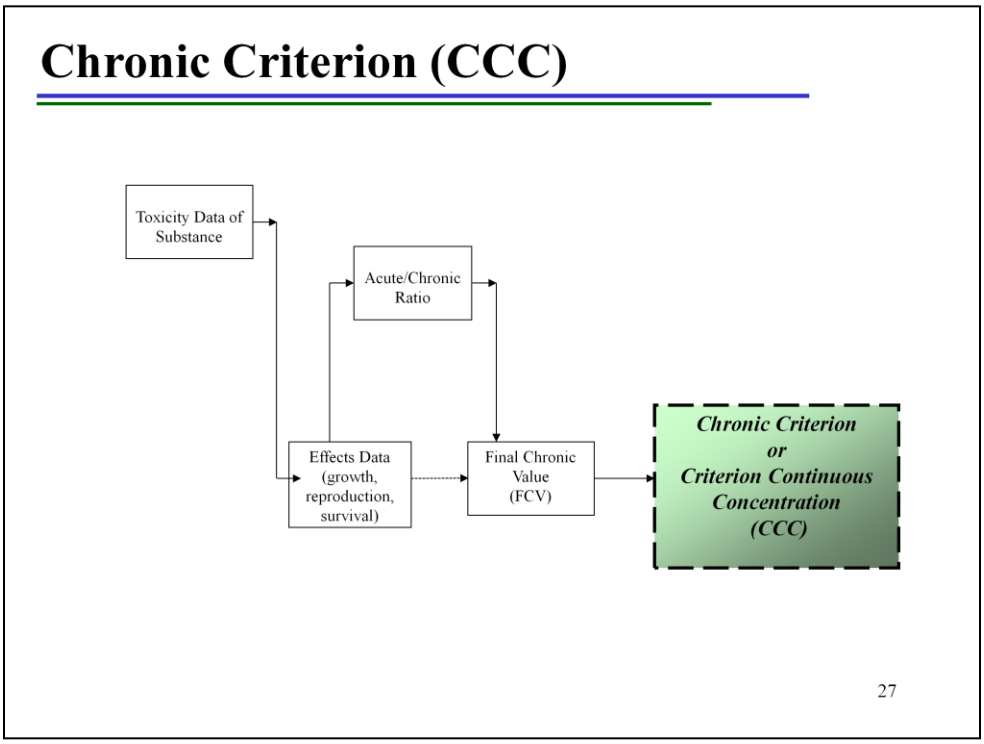
If chronic data are available from eight families, the same procedure used for calculating the FAV is used.

Otherwise, species Acute-Chronic Ratios are calculated. There is a requirement for 3 acceptable ACR values, which are then evaluated and generally the geometric mean for them is used.

If these ratios are acceptable (as explained in the guidelines), the Final Chronic Value is calculated by dividing the FAV by the Final Acute-Chronic Ratio (FACR).

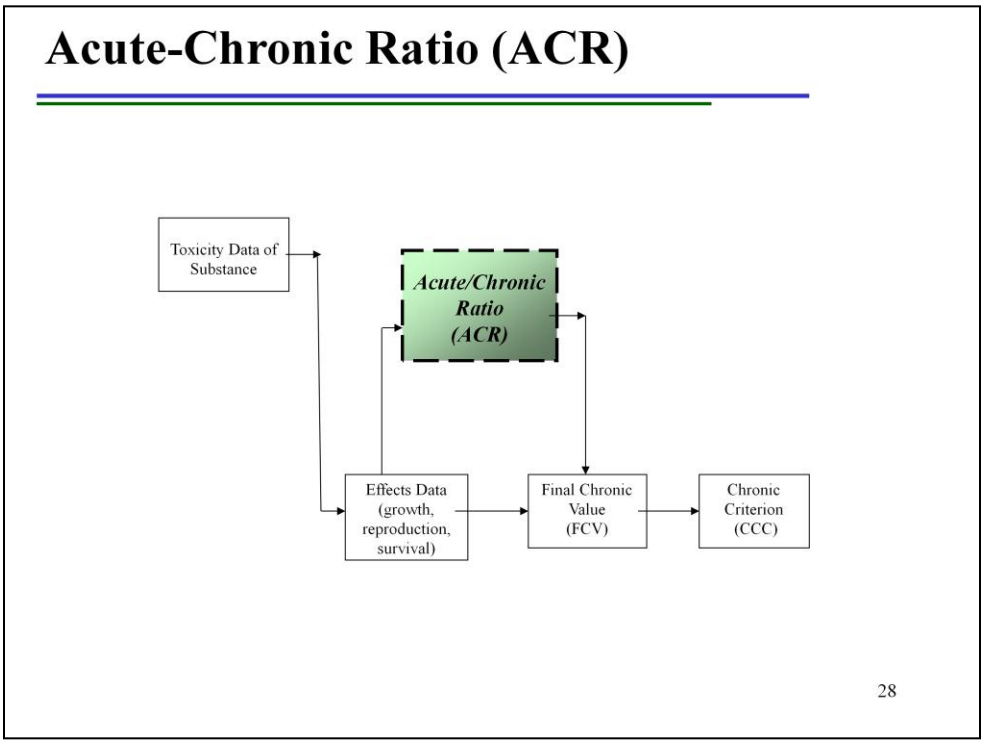
**If not enough acceptable ACRs, the Final Chronic Value cannot be calculated.

I will not be covering the plant value as we have traditionally not handled plant data independently. There is currently a review underway of potential methods for calculated criteria using plant values.

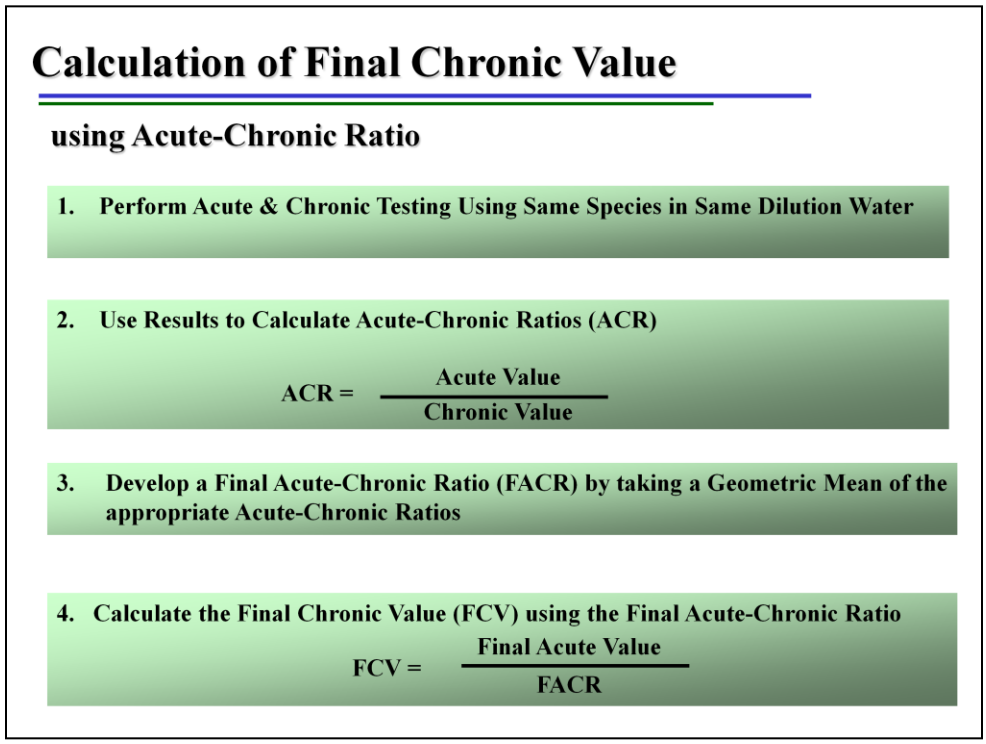


FCV=CCC if based on animal data or CCC can be adjusted down for considering Final Plant Value or comm/rec important animal sp.

Remember that if the Species Mean Chronic Value of a commercially or recreationally important species is lower than the calculated Final Chronic Value, the Species Mean Chronic Value should replace the Final Chronic Value.



Often there is not sufficient chronic tox test data for the 8 species from different families therefore the ACR can be used to derive a chronic criteria



Explain Calculation of Final Chronic Value

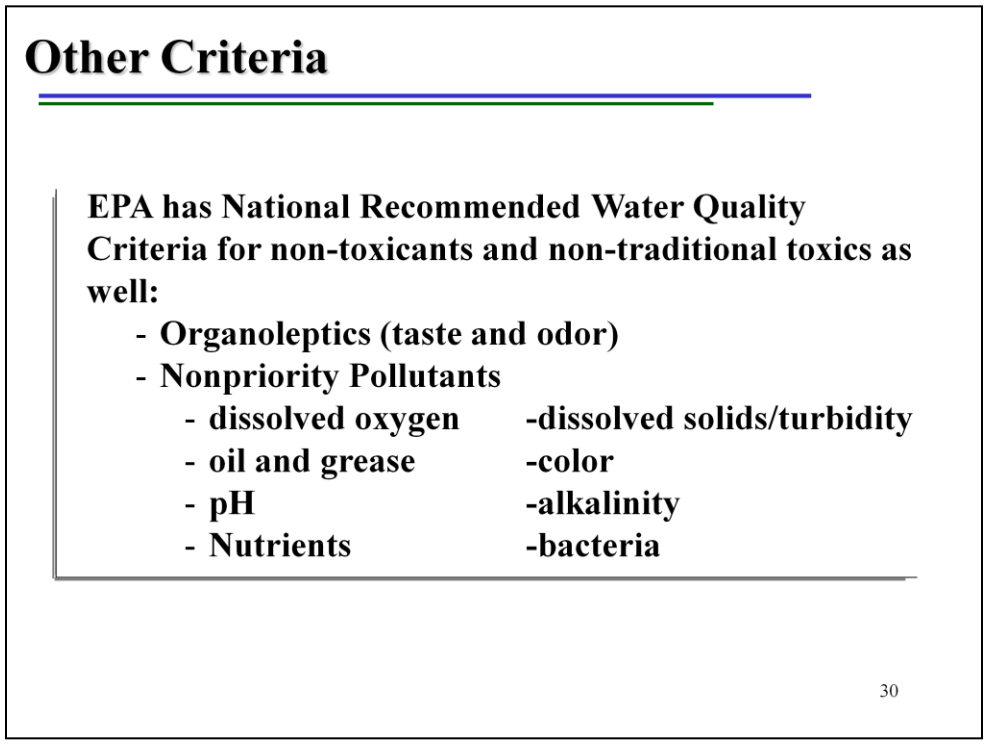
Final ACR = geometric mean of appropriate ACRs

The Final Chronic Value can then be generated by dividing the Final Acute Value by the Final ACR. This method is illustrated in the slide.

Need at least 3 acceptable ACRs to derive the CCC (2x fresh, saltwater)

You can use a commercially or recreationally important species value (FAV/2 or FCV) as the criterion where necessary. E.g. – trout are often sensitive and a criterion can be the lowest trout value to be protective.

We have calculator for doing these calculations. Not yet published on the web, but if there's a need, contact HECD.



Non-priority pollutants and organoleptic criteria.

Example of Aquatic Life Criterion

Chlordane

Based on procedures in the "Guidelines" (Stephan et al. 1985)
and
except possibly where a locally important species is very sensitive

Freshwater aquatic organisms and their uses should not be affected unacceptably if:

Acute - the short-term average concentration does not exceed 2.4 µg/L more than once every three years on the average, and

Chronic - the four-day average concentration of chlordane does not exceed 0.0043 µg/L more than once every three years on the average.

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This is an example ALC for Chlordane

The procedures described in the *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* indicate that, except possibly where a locally important species is very sensitive, [**FW or SW**] aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of [**name of pollutant**] does not exceed [**CCC]** µg/L more than once every three years on the average and if the one-hour average concentration does not exceed [**CMC**] µg/L more than once every three years on the average.

In the above text the appropriate information can be filled in accordingly:

- Either freshwater or saltwater is inserted at the first blank.
- The name of the pollutant is inserted at the second blank.
- The chronic effect concentration is inserted at the third blank as the Criterion Continuous Concentration (CCC).
- The acute effect-based Criterion Maximum Concentration (CMC) is inserted at the fourth blank.

Aquatic Life Criteria: Components

Question: **What is an Aquatic Life Criterion?**

Answer: **The highest instream concentration of a toxicant to which organisms can be exposed for a period of time without causing an unacceptable adverse effect.**

Question: **What is it intended to protect?**

Answer: **Aquatic animals (e.g., fish, invertebrates, crustaceans) and plants from acute and chronic exposure to a toxicant or condition.**

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A criterion is a measure of water quality designed to ensure the protection of designated uses. EPA's 304a criteria are developed as recommendations to assist States/Tribes in developing numerical and narrative criteria for their water quality standards.

Aquatic Life Criteria: Components

Question: What are the three components of an Aquatic Life Criterion?

Answer: Magnitude (how much)
- µg/L

Duration (how long)
- four days

Frequency (how often)
- once every three years

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Aquatic Life Criteria: Components

Question: **Are there "defaults" for these components of an Aquatic Life Criterion?**

Answer: **<u>Magnitude</u> (how much):**

- No. The concentration is based on toxicity testing.

<u>Duration</u> (how long):

- For acute exposure, 1-24 hour averaging period

- For chronic exposure, 4 day averaging period.

<u>Frequency</u> (how often):

- Once every 3 years, for both acute and chronic criteria.

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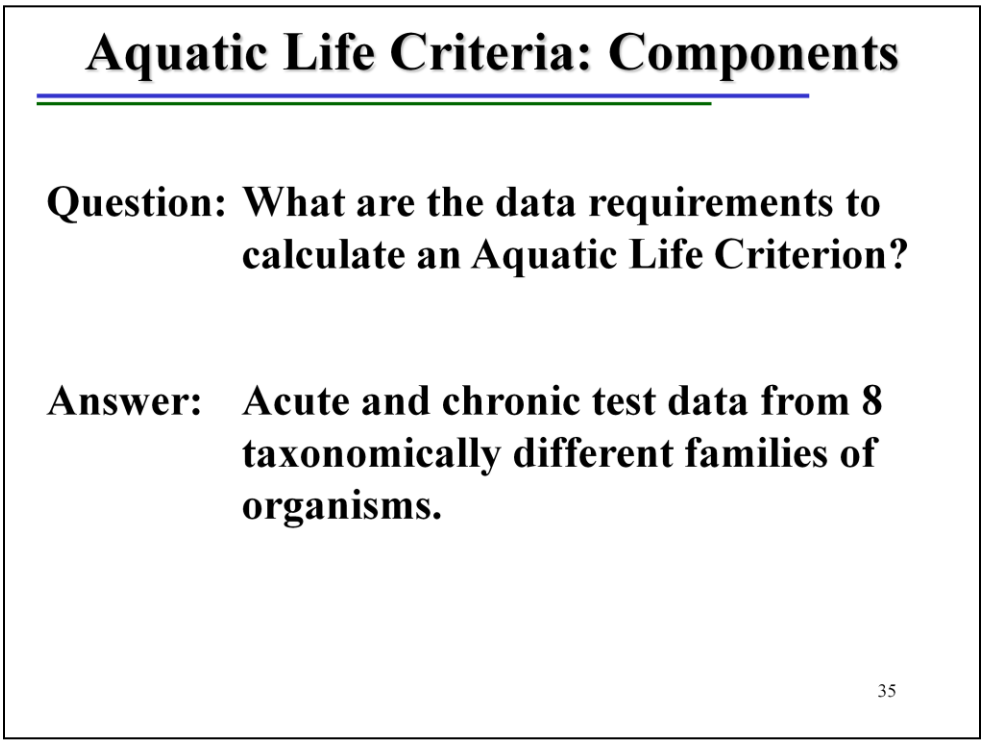
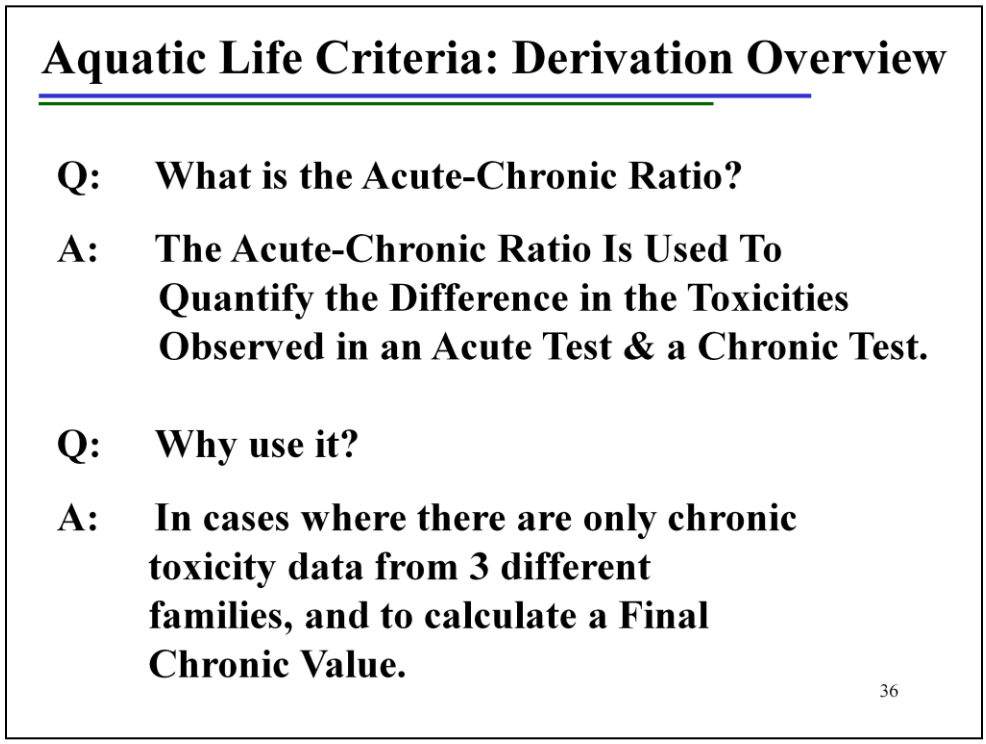


This slide provides an example. Data would include

- the family Salmonidae in the class Osteichthyes;
- a second family in the class Osteichthyes, preferably a commercially or recreationally important warmwater species (such as bluegill or channel catfish);
- a third family in phylum Chordata (such as another fish family or amphibian);
- a planktonic crustacean (for example, cladoceran or copepod);
- a benthic crustacean (such as ostracod, isopod, amphipod, or crayfish);
- an insect (a mayfly, dragonfly, damselfly, stonefly, caddisfly, mosquito, or midge);
- a family in a phylum other than Arthropoda or Chordata (such as Rotifera, Annelida, or Mollusca); and
- a family in any order of insect or any phylum not already represented (such as Mollusca).



Briefly Describe Acute-Chronic Ratio Concept

The Final Chronic Value can also be calculated by using an Acute-Chronic Ratio. An Acute-Chronic Ratio is used to quantify the difference in the toxicities observed in an acute test and a chronic test of the same species. This ratio and the Final Acute Value can then be used to derive a Final Chronic Value.

There are several methods for obtaining a Final Acute-Chronic Ratio, and you should refer to the guidelines for these methods.

Aquatic Life Criteria: Site-Specific Criterion
What is a Site?

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Explain Step 1, Definition of Site

Let's move on and briefly describe how site-specific criteria are formulated.

the first step is to define the site.

A site may be as small as a single point source discharge or quite large.

What is a Site?

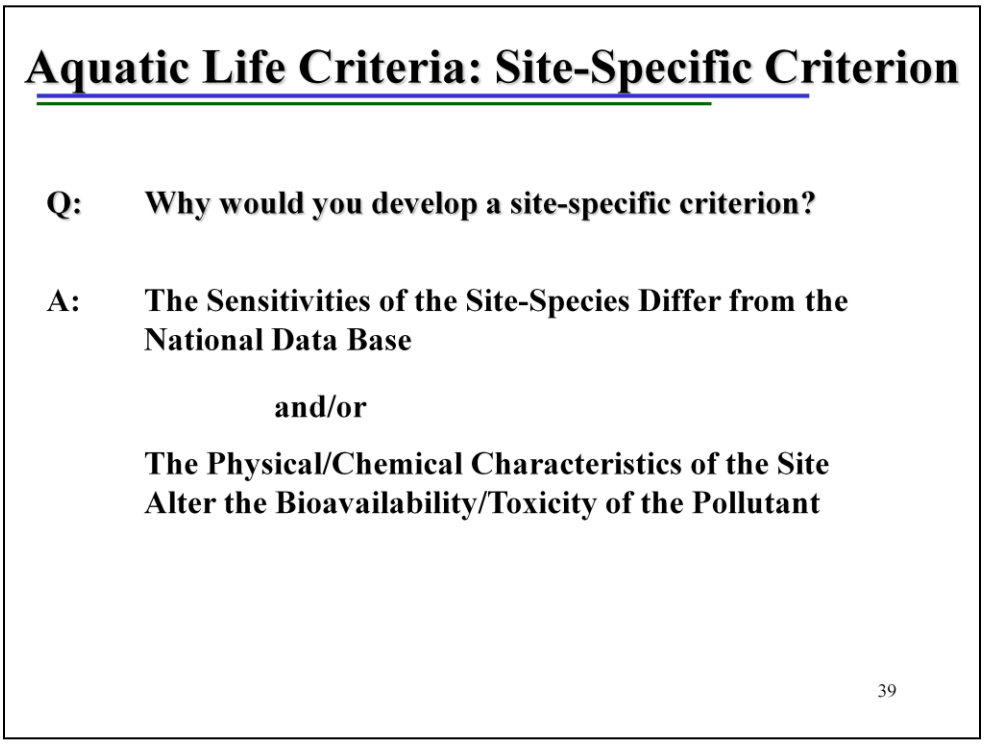
If water quality effects on toxicity are not a consideration, the site will be as large as a generally consistent biogeographic zone permits. ***(A biogeographic zone is an area classified by its distribution of animal and plant life.)***

For example, large portions of the Chesapeake Bay, the San Francisco Bay, Lake Michigan, or the Ohio River each may be considered as one site because their respective aquatic communities do not vary substantially.

The physical/geological conditions of a waterbody can also define the site. For example, in OK, there are natural deposits of sodium chloride which make flowing waters and ponds exceptionally salty. These types of conditions can define a site for these purposes.

Two additional factors must be considered in defining a site based on biological index:

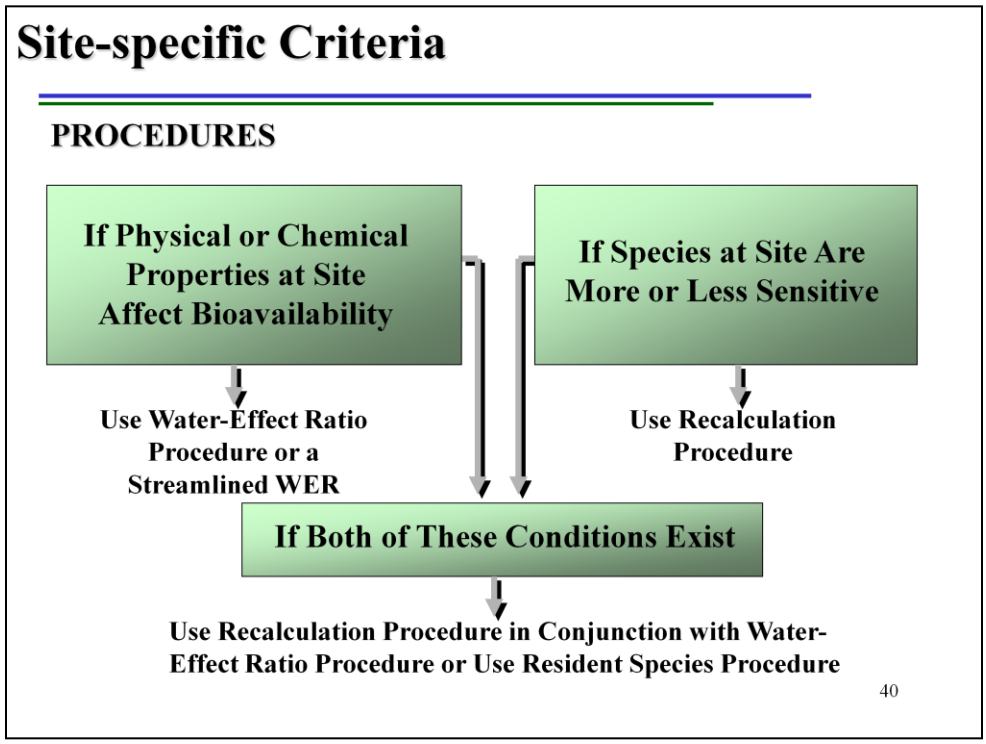
1. **information on viable communities in the site must be available; and**
2. **acceptable dilution water for the site must exist if testing using site water will be required.**



Explain Selection of Resident Species

A resident species is a species that occurs commonly or reproduces at the site of interest. **The sensitivity of this species may be different from that of the standard test species used to develop national criteria.**

A thorough evaluation of the site and its inherent biological and/or geophysical properties is necessary to determine applicability of site specific criteria.



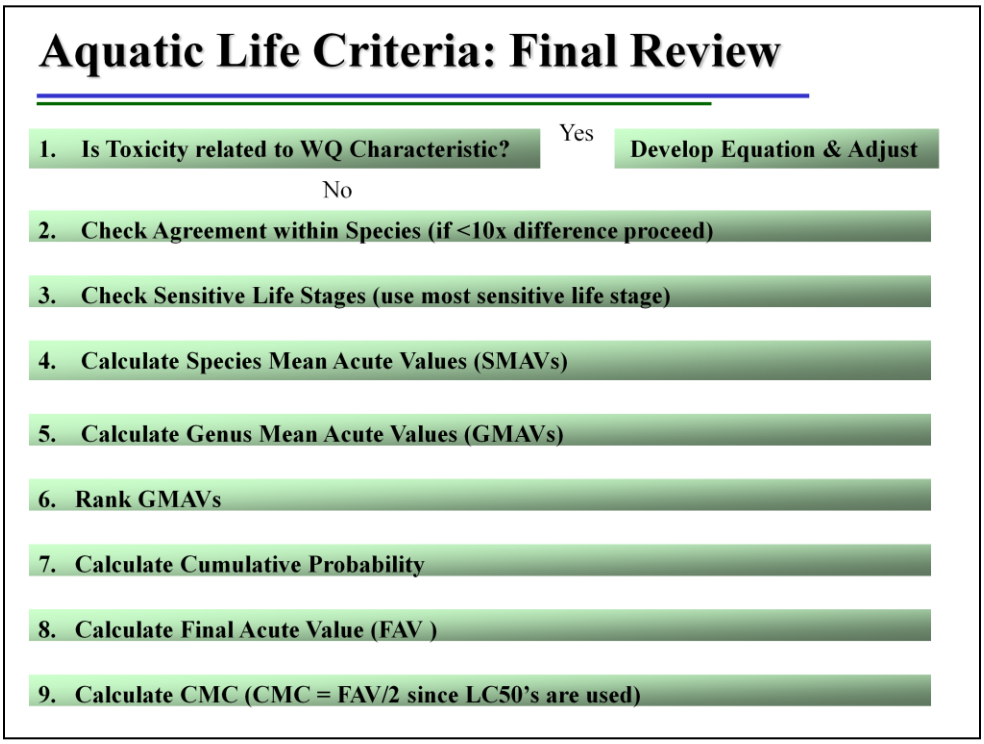
Explain Selection of the Procedure To Use

After appropriate species are selected, the next step is to select the type of procedure to use. This can be done using the following decision criteria.

1. If the sensitivity of site organisms is different and physical or chemical properties have no effect, use the Recalculation Procedure.

2. If physical or chemical properties affect bioavailability/toxicity and species sensitivity is similar, use the Water-Effect Ratio Procedure (formerly called the Indicator Species Procedure).

3. If both species sensitivity and physical or chemical properties affecting bioavailability apply at the site then use the Recalculation Procedure in conjunction with the Water-Effect Ratio Procedure or the Resident Species Procedure.



Explain Calculation of Final Chronic Value

The Final Chronic Value can then be generated by dividing the Final Acute Value by the Final Acute-Chronic Ratio. This method is illustrated in the slide.

Remember that if the Species Mean Chronic Value of a commercially or recreationally important species is lower than the calculated Final Chronic Value, the Species Mean Chronic Value should replace the Final Chronic Value.

So EPA has a number – Now What?

- EPA –Review Process
  - Internal Review
    - Expert EPA Peer Review
  - External Review
    - External Peer Review (external experts – multiple views)
    - Request for Scientific Views on Draft Criteria from the public via Federal Register
  - Publication of Final Recommended 304(a) criteria via Federal Register
- States Review and Adoption Process
  - Public Comment/Scientific Views on Draft EPA Criteria
  - Triennial Review/Adoption of Criteria into WQS
    - Public Comment/Scientific Views on Draft WQS according to States regulatory adoption process

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